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Concentration variations of several ions in stream after a wildfire

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Abstract: In May 2006, a high intensity wildfire occurred in Songling forest region in Daxing'an Mountains, China. The concentration changes of eight ions (K^+**,** Na^+**,** Ca^{2+}, Mg^{2+}, Cl^-, Br^-, NO_3^- and SO_4^{2-}) were measured in burned and unburned streams after fire from May to Oct., 2006. Results show that the most ions flux were higher in burned stream than that in unburned stream during the sampling period, and the greatest concentrations of most ions transported from burned stream occurred in July. After fire, the most amplitude chemical ion was Ca^{2+}, whose average concentration was 5.50 mg·L^{-1} higher than that in unburned stream, and the total concentration of every chemical ion presents a trend $Ca^{2+} > SO_4^{2-} > Na^+ > Mg^{2+} > NO_3^-$. The average concentrations of Ca^{2+}, SO_4^{2-}, Na^+, Mg^{2+}, NO_3^- showed an increase trend, but those of K^+, Cl^-, Br^- had a decreased trend. SO_4^{2-} had the largest loss among these anions, followed by NO_3^-. Overall, the increase degree of cation was greater than that of anion after burning.

Keywords: Forest fire; Stream; Water quality; Nutrients; Fire effect

Introduction

Fire is often instrumental in managing forest ecosystems (Frost 1995; Carignan *et al*. 2000; Engstrom *et al*. 2001). Numerous studies have suggested fires can alter the water quality of aquatic systems by causing varying responses in sediment, turbidity, temperature, nitrogen, phosphorus and cation levels (Tiedemann *et al*., 1979; Walbridge and Richardson, 1991). The magnitude of ion flux from catchments is thought to depend on fire severity because of modifications to cation exchange and biochemical reactions in the organic soil layer (Grier 1975; Stark 1977; Schindler *et al*. 1980).

A high intensity wildfire occurred in Songling forest region, Daxing'an Mountains, Heilongjiang, China, on May 23, 2006. The burned area was around 146 000 hm^2. A study on impact of fire on water quality of streams was conducted after the fire by Northeast Forestry University, Nan Kai University and Japanese copartner. This paper provides part of the study results, focusing on the concentration changes of several ions in the burned and unburned streams.

Site description and methods

Site description

The study site was located in Songling forest region (near the city of Jiagedaqi in Inner Mongolia), in the south of Yilehuli Mountain of Daxing'an Mountans. Songling forest region is one of the important timber production bases. The total area of forested land is 907 028 hm^2, with a forest coverage of 77.15%. *Larix gmelini* and *Betula platyphylla* are dominant tree species in the region. Climate of Songling belongs to cold temperate continental climate and is characterized by long cold winters and short hot summers. The average annual temperature ranges from 1ºC to 2ºC, and the absolute minimum and maximum temperatures are −43ºC and 36ºC, respectively. Annual rainfall ranges from 450 mm to 550 mm, and 60% of precipitation concentrates between July and August. Snow season is from the end of September to early May in the coming year, and the depth of snow is in range of 20–40cm. Most lowland streams in the region are intermittent, typically flowing from April to November.

A high intensity wildfire occurred on May 23, 2006 in Songling forest region and caused approximately 143 000 hm^2 of forest destroyed. The burned and unburned streams in studying area are the second branch (700 hm^2) and third branch (337.5 hm^2) of Xiaobadai River, respectively, and they both flow from south to north. Two sampled areas of burned and unburned streams with similar hypsometry, slope, aspect and geology were chose, which are located at the 80th compartment (burned) and 87th compartments (contrast) of Guyuan Forest Farm in Songling. The altitude of study site is about 500 m, with a slope of about 15º degree. The 80th compartment is composed of 17 sub-compartments, of which the 80% vegetation in the 1th, 2th, 3th, 9th and 11th sub-compartments were burned to death Before burning, the vegetation condition in 80th compartment is similar to that 87th compartment. The main tree species are *L. gmelini* and *B. platyphylla*, representative shrub species was *Rhododendron dauricum*, and the grass vegetation was mainly *Pyrola incarnata*. After burning, the trees were almost dead in the 80th compartment, shrub was mainly made up of *Betula fruticosa*, and grass vegetation was *Deyeuxia angustifolia*.

Methods

From late May to late October, water samples were collected using the pretreated plastic bottles in the middle part of the stream on the 25th of each month. Each sampling repeated three

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times. Water samples were filtrated, added with acid, and conserved at low temperature, and the contents of K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, Br^-, NO_3^- and SO_4^{2-} in the water sample were analyzed in the laboratory of Nan Kai University in Tianjin. The determination method of Cl^-, Br^-, NO_3^- and SO_4^{2-} is colorimetry, and that of K^+, Na^+, Ca^{2+}, Mg^{2+} is atomic absorption spectrophotometer.

Result and analysis

Changes of ion in stream after fire

The volume-weighted mean concentration and peak value of Ca^{2+}, Mg^{2+}, Na^+, NO_3^- and SO_4^{2-} transported from burned stream were higher than those from unburned stream (Table 1). This is mainly due to greater susceptibility of stream banks to erosion associating with the loss of litter cover and riparian vegetation (Townsend *et al*. 2000). Strong winds or intense rainfall, which may blow or carry ash into stream, after burning is possibly another reason for higher concentrations of Ca^{2+}, Mg^{2+}, Na^+, NO_3^- and SO_4^{2-}. During June, the concentration of nitrogen transported from the burned stream was 0.36 mg/L, which is lower than that (1.19 $mg{\cdot}L^{-1}$) from unburned stream, but in July it increased to 3.98 $mg{\cdot}L^{-1}$, which is much higher than that (0.93 $mg{\cdot}L^{-1}$) from unburned stream (Table1). High concentration of nitrogen in the burned watershed occurred in July mainly attributes to that July is greatest rainfall month and large quantities of ash was rushed into the stream. The volume-weighted mean concentration and peak value of K^+, Cl^- and Br^- transported from unburned stream were higher than that from burned stream. The reason is that wind dispersal could also remove ash from the burnt watershed, whilst some ash could be expected to be retained on the ground surface (Townsend *et al*. 2004).

Table 1. The concentrations of Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, Br^-, NO_3^- and SO_4^{2-} in burned and unburned streams in Songling forest region, Daxing'an Mountains

months	Na^+ ($mg{\cdot}L^{-1}$)		K^+ ($mg{\cdot}L^{-1}$)		Ca^{2+} ($mg{\cdot}L^{-1}$)		Mg^{2+} ($mg{\cdot}L^{-1}$)	
	unburned	burned	unburned	burned	unburned	burned	unburned	burned
May	2.25	1.68	0.86	0.50	4.16	4.98	0.68	0.88
June	3.22	2.73	0.16	0.46	2.62	6.32	0.22	0.85
July	2.37	8.87	0.24	1.91	3.31	18.40	0.50	3.26
Augest	2.72	2.66	2.88	0.12	4.23	4.09	0.14	0.74
September	2.42	4.44	0.19	0.23	1.87	8.35	0.14	1.54
October	1.82	3.65	0.13	0.14	1.26	8.34	0.11	1.29
average	2.47	4.01	0.74	0.56	2.91	8.41	0.30	1.43

months	Cl^- ($mg{\cdot}L^{-1}$)		Br^- ($mg{\cdot}L^{-1}$)		NO_3^- ($mg{\cdot}L^{-1}$)		SO_4^{2-} ($mg{\cdot}L^{-1}$)	
	unburned	burned	unburned	burned	unburned	burned	unburned	burned
May	0.15	0.38	0.13	0.13	0.27	0.11	3.13	3.94
June	2.06	0.56	0.25	0.19	1.19	0.36	3.09	2.97
July	1.69	0.65	0.35	0.10	0.93	3.98	4.92	20.02
Augest	0.91	0.20	0.11	0.11	0.21	0.24	0.59	3.76
September	1.35	0.65	0.10	0.08	1.11	0.19	2.24	1.42
October	0.26	0.83	0.10	0.27	1.57	2.25	6.12	9.88
average	1.07	0.54	0.17	0.15	0.88	1.19	3.35	7.00

After fire, the most amplitude chemical ion in burned stream was Ca^{2+}, whose average concentration was 5.50 $mg{\cdot}L^{-1}$ higher than that in unburned stream, and the average concentration of other chemical ions presented a trend as SO_4^{2-}(3.65 $mg{\cdot}L^{-1}$)＞Na^+(1.54 $mg{\cdot}L^{-1}$)＞Mg^{2+}1.13 $mg{\cdot}L^{-1}$＞NO_3^-0.31 $mg{\cdot}L^{-1}$. The average concentrations of K^+, Cl^- and Br^- decreased by 0.54 $mg{\cdot}L^{-1}$, 0.18 $mg{\cdot}L^{-1}$ and 0.02 mg/L, respectively (Table 1). Calcium is vulnerable to leaching and exists in soil in large quantities, so it is the most amplitude chemical ions after fire. Nitrate is a form of water-soluble inorganic nitrogen and easy to be absorbed by plants, but it can not be adsorbed by soil colloids. Nitrate exists in soil solution and can be easily leached (Luo 2002). Chandler *et al* (1983) reported that nitrogen was the nutrient most vulnerable to depletion by burning because large amounts were volatilized and lost to the atmosphere. Our study result on nitrate agrees with Chandler's. We also found that NO_3^- had larger loss (Fig. 3). Overall, the increase degree of cation was greater than that of anion after burning, and the reason for that is the soil colloid absorbs cation, and after fire, the soil colloid is destroyed and causes the loss of cation.

Comparison of ion changes among different months

The highest concentrations of most measured ions in burned stream occurred in July (Fig. 1), which is the greatest rainfall and runoff season in Daxing'an Mountains, due to the leaching of nutrient elements from canopy and ashes during the season. This result is in agreement with the report of Gerla *et al* (1988) that the greatest concentration values of most constituents occurred in the season with greatest rainfall and runoff. The occurrence of highest concentration values of measured ions is not regular in unburned stream (Fig. 2) compared with those in burned stream. The results mean that burning will cause the loss of nutrient ions and increase erosion to some extent. Similar result also was reported, and Clayton (1976) found that during fires, nutrients are lost through atmospheric transport of gases and particulates (although these losses may be added as deposition elsewhere) and, for longer periods following the fire, through increased erosion and runoff.

The highest value of SO_4^{2-} concentration was higher than other

ions in both burned and unburned streams (Figs. 1 and 2) because of strong migration characteristics of sulfur (SO_4^{2-} form). It was measured by Ma (1993) that the water transfer coefficient of sulfur is n×10^2. The peak values of potassium concentration occurred in July in burned stream and August in unburned stream, which attributes to high-intensity rainfall and large surface runoff in July and August. Potassium is easily leached from soil, ash and decomposing organic material and thus gives a clear signal of the development of leaching (Malmer 2004) and potassium is also linked to the most soluble elements, whose average concentration will increase after canopy leaching (Ma 1993). The concentrations of the most anion showed an increase trend in October (Table 1), which may ascribe to the low water yield in this month.

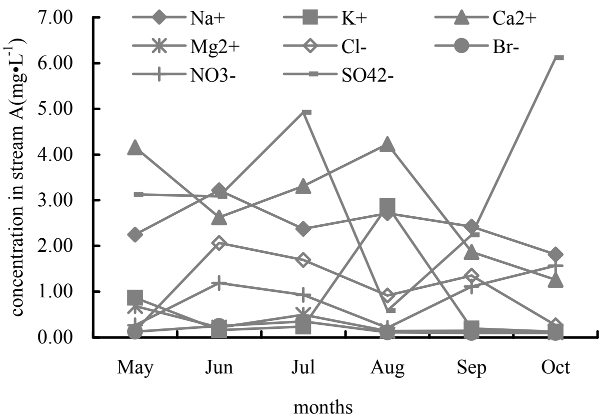

Fig. 1 The concentration change of ions in different months in burned stream in Songling forest region of Daxing'an Mountains after a high intensity fire

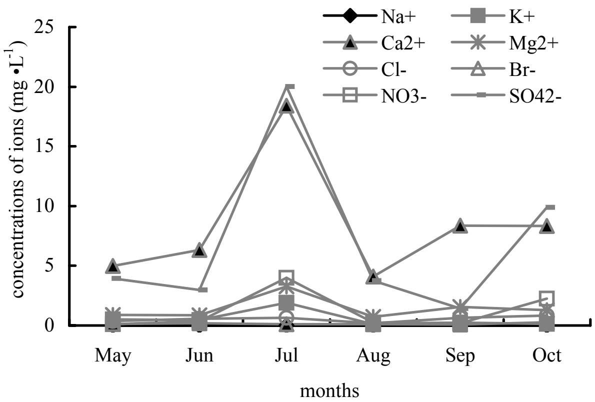

Fig. 2 The concentration level of ions in in different months unburned stream in Songling forest region of Daxing'an Mountains after a high intensity fire

Conclusion

Burning can increase the export of ions by virtue of the loss of litter cover and riparian vegetation, and greater area of bare ground. The greatest concentrations of most ions transported from burned stream occurred in July corresponding to the period of greatest seasonal rainfall and runoff, indicating that burning may increase soil erosion and the nutrient lost from forest. After fire, the average concentrations of Ca^{2+}, SO_4^{2-}, Na^+, Mg^{2+}, NO_3^- showed an increase trend but that of K^+, Cl^-, Br^- had a decrease trend. The concentration of Ca^{2+} increased sharply and it was 5.50 mg·L^{-1} higher than that in unburned stream. The highest value of SO_4^{2-} concentration was higher than other ions in both burned and unburned streams (Figs. 1 and 2) because of strong migration characteristics of sulfur (SO_4^{2-} form). The peak values of potassium concentration occurred in July in burned stream and August in unburned stream,

References

Battle, J., Golladay, S. W. 2003. Prescribed fires impact on water quality of depressional wetlands in southwestern Georgia. *Am. Midl. Nat.*, **150**: 15−25.

Carignan,R., D'Arcy, P. and Lamontagne, S. 2000. Comparative impacts of fire and forest harvesting on water quality in Boreal Shield lakes. *Can. J. Fish. Aquat. Sci.*, **57**(Suppl. 2): 105−117.

Clayton, J. L. 1976. Nutrient gains to adjacent ecosystems during a forest fire – an evaluation. *Forest Sci.*, **22**: 162−166.

Engstrom, R. T., L. K. Kirkman and R. J. Mitchell. 2001. The natural history of the fire forest, p. 5-17. In: J. R. Wilson (ed.), The fire forest: longleaf pine-wiregrass ecosystem. Georgia Wildlife Federation, Vol. 8, No. 2.

Frost, C.C. 1995. Presettlement fire regimes in southeastern marshes, peatlands, and swamps, p.39-60. In*:* S. I. Cerulean and R.T. Engstrom (eds.), Fire in wetlands: a management perspective. Proceedings of the Tall Timbers Fire Ecology Conference, No. 19. Tallahassee, Florida: Tall Timbers Research Station.

Gerla, P.J. Galloway, J.M. 1988. Water quality of two streams near Yellowstone Park, Wyoming, following the 1988 Clover-Mist wildfire. *Environmental Geology*, **36**: 127−136.

Grier, C.C. 1975. Wildfire effects on nutrient distribution and leaching in a coniferous ecosystem. *Can. J. For. Res*., **5**: 599−607.

Luo Ruying. 2002. *Soil Science*. Beijing: China Forestry Publishing House (in Chinese).

Malmer, A. 2004. Stream water quality as affected by wildfires in natural and manmade vegetation in Malaysian Borneo. *Hydrol. Process*, **18**: 853-864.

Ma Xuehua. 1993. *Forest Hydrology*. Beijing: China Forestry Publishing House (in Chinese).

Schindler, D.W., Newbury, R.W., Beaty, K.G., Prokopowich, J., Ruszcynski, T. and Dalton, J.A. 1980. Effects of a windstorm and forest fire on chemical losses from forested watersheds and on the quality of receiving streams. *Can. J. Fish. Aquat. Sci.*, **37**: 328−334.

Stark, N.M. 1977. Fire and nutrient cycling in a Douglas-fir/larch forest. *Ecology*, **58**: 16−30.

Tiedemann, A. R., Conrad, C.E., Dieterich, J.H., Hornbeck, J.W., Megahan, W.F, Viereck, L.A. and Wade, D.D. 1979. Effects of fire on water, U.S. Department of Agriculture Forest Service. Gengeral Technical Report WO-10.28 p.

Townsend, S.A., Douglas, M.M. 2000. The effect of three fire regimes on stream water quality, water yield and export coefficients in a tropical savanna (northern Australia). *Journal of Hydrology*, **229**: 118–137.

Townsend, S.A., Douglas, M.M. 2004. The effect of a wildfire on stream water quality and catchment water yield in a tropical savanna excluded from fire for 10 years (Kakadu National Park, North Aus- tralia). *Water Research*, **38**: 3051–3058.

Walbridge, M.R. and Richardson, C.J.. 1991. Water quality of pocosins and associated wetlands of the Carolina Coastal Plain. *Wetlands*, **11**: 417−439